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COMMITTEE ON
THE CHALLENGES OF
MODERN SOCIETY

AIR POLLUTION EMISSIONS INVENTORY SYSTEMS

Number 104

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This report describes how an emissions inventory system should be organized and operated.

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AIR POLLUTION EMISSIONS INVENTORY SYSTEMS

A Report of the NATO/CCMS Pilot Study
on Air Pollution Assessment Methodology and Modeling

N. 104

COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY
NORTH ATLANTIC TREATY ORGANIZATION
October 1978

Preface

The North Atlantic Treaty Organization (NATO) established the "Committee on the Challenges of Modern Society" (CCMS) at the November 1969 meeting of the North Atlantic Council.

The CCMS was charged with developing meaningful environmental and social programs that complement other international programs, and with showing leadership, first, in solution of existing problems and, second, in development of long-range goals for environmental protection in the NATO sphere of influence and in other countries as well. A first Pilot Study on Air Pollution was initiated by the CCMS at its inaugural meeting in December 1969. The United States (Environmental Protection Agency) has been the pilot nation with the Federal Republic of Germany (Federal Ministry of the Interior) and Turkey (Scientific and Technical Research Council) as copilot-nations.

The Pilot Study on Air Pollution was an action program designed to demonstrate and encourage the utilization of existing knowledge for the development of air quality management programs. It entailed the demonstration of a system approach to air quality management. Case studies have been carried out in Ankara, Turkey; Frankfurt, Federal Republic of Germany; St. Louis, U. S.; Oslo, Norway; South Holland Region, The Netherlands (NATO/CCMS Report No. 6, Appendices A - E).

The results of the pilot study are documented in NATO/CCMS Report No. 6 (Revised) "Guidelines to Assessment of Air Quality" of October 1972 and in NATO/CCMS Report No. 33 (Final Report) containing 15 recommendations as well as in several other documents, listed as Annex II to this document.

Starting from three of the above recommendations (VI, VII and XIV) the Federal Republic of Germany proposed to initiate a new Pilot Study on Air Pollution Assessment Methodology and Modeling at the CCMS Plenary Session on October 22 and 23, 1974.

These NATO/CCMS Recommendations are:

RECOMMENDATION VI

Member nations will co-operate to develop standardized methods for emissions data storage and retrieval to support requirements in the conduct of national air quality management programs. The US National Emission Data System (NEDS) might serve as a model for a common international system.

RECOMMENDATION VII

Member nations will co-operate to develop standardized techniques for projecting emissions and predicting future ambient air quality.

RECOMMENDATION XIV

Member nations agree the CCMS modeling activity has shown that there is a widespread need for further international co-operation to accomplish the following tasks:

Bring together model developers and air quality managers for exchange of ideas, discussion of users' needs and demonstration of modeling techniques.

Standardize modeling techniques for specific air quality management applications and consider how computerized models might be made available for all users.

Continue to review on-going air quality assessment studies.

In spring 1975 the North Atlantic Council approved the German proposal. The pilot study work started with the Federal Republic of Germany (Federal Ministry of the Interior) as pilot nation and the United States of America (Environmental Protection Agency) and Belgium (Service du Premier Ministre) as co-pilot nations:
A Working Group and two Panels were established with the following functions:

Assessment Methodology Panel

- Pursue and carry out Recommendations VI and VII
- Continue to review present and future assessment studies with respect to the application of assessment methodology.

Modeling Panel

- Develop standardized models for various air quality management applications.
- Develop programs to improve modeler/user communications in conjunction with the Assessment Methodology Panel and the Working Group.
- Continue as an information forum on new modeling concepts and techniques, organizing once a year international technical meetings on air pollution modeling and its application.

In addition the Working Group established an Ad-Hoc Group on Air Quality Management Systems to revise and update the NATO/CCMS Report No. 6 (Revised) 1972 by preparing a new document on "Guidelines to Air Quality Management Systems".

Another Ad-Hoc Group was set up for compiling a Glossary of Terms frequently used in assessment methodology, modeling and air quality management systems.

As an outcome of this Pilot Study on Air Pollution Assessment Methodology and Modeling the following NATO/CCMS documents are published (see also Annex III):

Air Quality Management System

- Guidelines to Air Quality Management System.

Assessment Methodology

- Air Pollution Emission Inventory Systems
- Air Pollution Emissions Projecting

Air Pollution Modeling

- Introduction to Air Quality Modeling
- Uses and Needs for Air Quality Modeling
- Bibliography on Grey Literature on Air Quality Modeling, Part I (Applied Models)
- Bibliography on Grey Literature on Air Quality Modeling, Part II (New Modeling Techniques)
- Practical Demonstration of Multiple Source Urban Air Quality Modeling (Gaussian Plume)
- Fundamentals for the Applications of a Gaussian Plume Model

Other Publications

- Glossary of Terms
- Proceedings of the 6th to 9th International Technical Meetings on Air Pollution Modeling and its Application
  (6th Meeting, 24. - 26. Sept. 1975, Frankfurt/Main, Germany)
  (7th Meeting, 7. - 10. Sept. 1976, Airlie House, USA)
  (8th Meeting, 20. - 23. Sept. 1977, Louvain-la-Neuve, Belgium)
  (9th Meeting, 29. - 31. Aug. 1978, Toronto, Canada).

The chairman of the Working Group wishes to acknowledge the scientists participating from pilot, copilot, and observer countries, and the many other persons, who assisted in the preparation of this document.

The panel, which performed diligently throughout the course of this effort, receives the highest praise. The panel members were:

Federal Republic of Germany - Pilot Country

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The addresses of the panel members are listed in Annex I.

Full recognition is given to each panel member for carrying out and coordinating review and other activities related to the development of this document in his respective country and to Ms. C. Morawa of the Federal Environmental Office, Germany for her effort in coordinating and organising and for editorial work.

For the Working Group,
Erich Weber, Chairman.

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Appendix (Bound as a separate volume)

- A Air Pollution Emissions Inventory Systems used in Belgium
- B Air Pollution Emissions Inventory Systems used in Canada
- C Air Pollution Emissions Inventory Systems used in the Federal Republic of Germany
- D Air Pollution Emissions Inventory Systems used in the Netherlands
- E Air Pollution Emissions Inventory Systems used in Norway
- F Air Pollution Emissions Inventory Systems used in the United States of America

1. Introduction

Many activities within an air quality management system require the use and assessment of various types of air pollution data. Data on air pollutant emissions and air quality data are the most important of these data types. An emissions inventory system supports pollution assessment activities by collecting, screening, storing, and presenting emissions data in a systematic and useful manner. The purpose of this document is to describe how an emissions inventory system should be organized and operated. The Appendix presents a number of technical papers on emissions inventory systems used in the North Atlantic Treaty Organization/Committee on the Challenges of Modern Society (NATO/CCMS) countries.* Participating countries which have emissions inventory systems are Belgium, Canada, the Federal Republic of Germany, Italy, the Netherlands, Norway and the United States of America.

2. Purpose and Scope of an Emissions Inventory

2.1 Definition

An emissions inventory is a set of information on sources and emissions of air pollutants in a given area. Both man-made and natural emissions may be included. Data is generally categorized in some detail by type of pollutant, source type or category and source location. Emissions estimates or projections are usually made for specific time periods. Thus, an emissions inventory provides a more or less detailed description of the air pollutant emissions within a specific area or region.

* The Appendix is bound as a separate volume.

An emissions inventory system is the method by which an emissions inventory is compiled and maintained. Generally, this will include collection, screening and refining, storage, and summary and retrieval of data related to emissions.

2.2 Objectives

The contents of an emissions inventory and the elements of the emissions inventory system are determined by the use that will be made of the data. For this reason, the objectives of an emissions inventory system within the air quality management system (AQMS) should be carefully evaluated as the first step in developing the emissions inventory system. Such objectives may be, for example:

- the assessment of the current emissions situation in a certain area, such as determining the contribution from the various emitter categories
- the prediction of changes in the emissions situation due to the addition of new air pollution sources
- the prediction of changes in the emissions situation due to certain control strategies
- the prediction of changes in the ambient air quality from the above-mentioned changes in the emissions situation
- the development of abatement and control procedures
- design and management of air quality monitoring networks

For most of these applications, information is required on the type of pollutants, the mass flow rate of the emissions, the cause and location of the emissions, and the times at which they take place. Data on the emitters may also be included.

The objectives of the emissions inventory will also determine the amount of detail required (resolution). A comprehensive emissions inventory may, for instance, include detailed information on industrial installations, their mode of operation, their exact geographic location and the time when the emissions take place. Less detailed inventories may deal only with total emissions in certain regions, presented as yearly averages.

Finally, the use of the data determines the required accuracy with which the data should represent the current emissions situation and, thus, also dictates the frequency of updating of the emissions inventory.

2.3 Costs

Since the objectives of an emissions inventory determine the contents of the data bank, the degree of detail in the data, and the accuracy of the data, they also will determine the costs of establishing and maintaining the inventory. Prior to the development of an emissions inventory, these anticipated costs should be carefully evaluated. Not only should the costs associated with the first round of collection, storage, and processing of data be considered, but also those associated with the updating and maintenance of the system.

2.4 Relation to other Data Banks

In some cases, an air pollution emissions inventory is combined or coordinated with inventories of other emissions, such as those causing water, waste, and noise pollution. (See, for example, the Dutch and Norwegian technical papers.) It may then be useful to consider the particular aspects of these additional forms of pollution, along with those of air pollution. If feasible, it may even be advantageous to consider one system containing all desired types of emissions information or, at a minimum, a set of compatible systems.

Existing statistical data banks (e. g., data on industry, transportation, population, energy consumption, meteorology, etc.) may be particularly useful in providing such data to an air pollution emissions inventory. Provisions for an easy flow of such data into the emissions inventory would then be required.

3. Principles

3.1 Elements of Emissions Inventory Systems

The establishment and development of an emissions inventory system requires an effective coordination of the following elements:

- data collecting
- data refining
- data processing (storage and availability)
- data evaluation (retrieval and summary)

When this coordination is reached, the emissions inventory can serve as a valuable tool in air pollution management.

3.1.1 Data Collecting

When collecting data, all causes of emissions fall into one of the following emitter categories:

- major industrial facilities*
- small industrial facilities
- domestic consumers
- transportation
- natural causes

Within the above-mentioned emitter categories, different procedures of data collection may be applied or combined. These include:

- using emission factors
- using questionnaire forms
- performing source testing and/or other special studies

In data collecting, two approaches may be used: the individual approach as described in 4.1.2 and the collective approach as presented in 4.1.3.

Sources may be grouped into three types: line, point, and area. Major industrial facilities are often dealt with as point sources. Line sources usually pertain to traffic

* In this context, "industrial facilities" also includes agriculture, mercantile trade, services, etc.

emissions, while area sources encompass emissions from domestic consumers or smaller industries. However, all three types of sources may be used in describing the emissions of industrial facilities:

- point sources correspond to well-defined outlets such as stacks
- line sources may correspond, for example, to roof outlets or a number of small point sources arranged in a line
- area sources may encompass smaller sources distributed over a large plant area (e. g., leakages, emissions from storage tank fields, and small point sources)

The concept of area sources also may be used to group together all emissions within an area without distinguishing between the different emitter categories listed above.

The collection of data varies from one country to another, and the reader is directed to the various technical papers contained in the Appendix to obtain further details. There is, however, one basic difference in the approach used by European countries as opposed to that used by North American countries. In Europe, most emissions inventories have been carried out over a limited area, but very comprehensively, whereas North American inventories have been conducted nationwide. The difference in approach stems from a differnce in objectives.

3.1.2 Data Refining

In the context of an emissions inventory system, data verification and data auditing procedures are absolutely necessary. This applies whether the emissions data are evaluated manually or by computers. It can be done directly after data collection, after data storage, or with data summaries, in manual or computerized form. Additional information on data refining is presented in 4.2.1.

3.1.3 Data Storage and Availability

As an emissions inventory is a systematic collection of a large amount of detailed data, it is necessary to have a system that allows effective processing, storage, and retrieval of the data.

The decision to use computers or to employ a manual approach for the emissions data processing system is important. The procedures and the medium of data storage should be developed after a thorough evaluation of the expected volume of data and frequency and types of uses and updates. Obviously, a small data base which essentially will never be updated or updated infrequently is most appropriately stored manually (e. g., on the original data forms or on coded cards). Manual data storage also may be cost-effective for large data bases which will seldom be changed.

If there is a large set of data requiring frequent modification and sophisticated summarization and retrieval, automatic data processing is necessary. It should be noted, however, that once the file format has been selected and the computer software developed, it is very costly and time-consuming to make essential changes.

If time or cost constraints dictate incremental development of the inventory, such as starting with an inventory for one pollutant or for pollutants from one type of plant (e. g. combustion for heating purposes), the medium of data storage should be decided upon with respect to the overall goals of the AQMS and the desired future form of the emissions inventory. Therefore, if a comprehensive, regularly updated emissions inventory is to be a part of the AQMS, consideration of data processing by computers at the onset is recommended.

Experiences gained in Canada in establishing a computerized emissions inventory system from a manual system are of interest. A summary of this approach is described in Paragraph 6.2.

3.1.4 Data Retrieval and Summary

A main objective of an emissions inventory system is to provide the users with pertinent and timely information. To achieve this, the system must be designed by first defining user requirements, and then identifying the data needed to parovide this information and the retrieval and summary capability necessary to produce desired data in a timely and useful manner.

A manually-based emissions inventory has only limited possibilities of providing the user with summaries and various retrieval scenarios. A computerized emissions inventory system, on the other hand, allows a multitude of summaries and retrievals. Data can be retrieved from a system according to various basic arrangements such as:

- emissions according to source category
- emissions according to pollutants
- emissions within a specific geographical region

Any of these groupings can be used by itself or in combination to display emissions data. Summaries and evaluations of emissions data can be performed via selections according to a number of codes, such as the following examples used by the Federal Republic of Germany and/or the United States of America:

- source classification code
- source code
- estimating method code
- pollutant code
- computed emissions
- control equipment code
- control efficiency code
- gas cleaning unit code
- operating rate
- location coordinates
- sulphur content of fuel
- source height
- emission rate

Evaluations using combinations of above mentioned codes then may include, for instance:

- emission tabulation by source category, plant, region, etc.
- contributions of specific sources to emission totals
- emission density maps for stationary and mobile sources
- emission arranged by pollutant
- time fluctuation of emissions
- evaluation of changes in control equipment or fuels

The emissions inventory data systems of the United States and Germany serve as bases for demonstrating evaluation possibilities. Comprehensive data banks developed from the above mentioned systems include those of Canada (developed from the United States' system) and the Netherlands and Belgium (developed from the German system).

3.1.5 Updating

The purpose of pollutant emissions inventory is best served when the inventory is up-to-date. The emissions inventory system should, therefore, include procedures for the submission of data to the responsible organization, as well as for collection or development and entry of data by that organization.

3.2 Resolution of Information

Emissions inventory systems can be developed to many different degrees of detail or resolution. The Norwegian example of a sulfur dioxide (SO_2) emissions inventory of the entire country has low resolution with regard to space. Similar inventories have been developed in other countries and states. A highly detailed resolution should be sought for emissions inventories to be used for planning purposes, while more aggregated inventories may be sufficient for other purposes.

3.2.1 Criteria for Resolution

The future uses of an emissions inventory system within an AQMS define the types and degrees of resolution necessary in the inventory. Listed below are four examples of uses

of an emissions inventory with distinctly different requirements as to resolution of space, time, pollutants, and sources.

(1) A general collection of emissions information to be used in explaining measured air quality

(2) A base of emissions data for land use, urban, and regional planning

(3) A file of information relevant to plant licensing, for licensing authorities

(4) A compilation of data related to air pollution control plans or strategies

3.2.2 Spatial Resolution

For only a general description of emissions, spatial resolution need not be very great. For example, information may only be required at the regional level. An emission inventory for SO_2 in Norway has a grid size of 55 km x 55 km and a German SO_2 and dust inventory has a grid size of 70 km x 70 km. Such systems may provide emissions estimates only for these relatively large areas, and a resolution of several kilometers may be sufficient.

For land use, urban, or regional planning, for plant licensing or for air pollution control planning, the spatial resolution required depends on the size of the country or other area covered and on the distribution of emission sources and receptors (e. g. residential areas). Less resolution will be required where sources and receptors are far apart or restricted to specific areas; higher re-

solution is necessary where development is more concentrated and there is more mixing of sources and receptors. The American emission inventory system allows entry of coordinates with a resolution of 100 meters; the Dutch system specifies locations to 10 meters and the German system allows for a resolution as fine as 1 meter.

3.2.3 Temporal Resolution

Time spans used in the emissions inventory system may be predetermined (e. g., seasonal, daily, hourly) or may vary as a function of the activity being inventoried. The operation of the activity, the production cycle and/or its emission or production instrumentation may determine the temporal resolution permissible or required.

Minimal resolution with respect to time might include seasonal variations in emission rates, such as that used in the emission inventory for Norway. Emission data to be used for land use planning should be coordinated with the various ambient air quality standards on which the AQMS is based. For example, the United States has standards with averaging periods from 1 hour to 1 year, while Germany's standards are based on measurements with an averaging period of half an hour.

Emissions data must be of fine resolution to be used in plant licensing. Systems used in Belgium, Canada, Germany, Norway, Netherlands and the United States allow resolution to 1-hour periods. It is generally necessary to define actual emissions and the times in which they occur (e. g. hours/day, days/week and weeks or months per year).

Emissions information to be used in dispersion modeling should include the time of day or night and seasonal fluctuations, due to the necessity to coordinate with meteorological phenomena which may vary significantly from day to night or season to season. For example, emissions from traffic follow very distinct daily and seasonal cycles. Resolution of emissions on a daily and seasonal basis will generally be sufficient for air quality control planning and development of control strategies.

3.2.4 Pollutants Inventoried

In all emissions inventories, a distinction must be made between the principal air pollutants of concern. Generally, SO_2, oxides of nitrogen (NO_x), carbon monoxide (CO), hydrocarbons, and particulates are included. While other pollutants may be important, inclusion of them in a general emissions inventory (e. g. regional-scale resolution) may not be advisable due to distortion which would occur in averaging over an extensive area.

Consideration of specific hazardous pollutants (e. g. asbestos, fluorides, vinyl chloride) is important in land use planning. Equally high resolution is required in an emissions inventory to be used in licensing in order to allow full comparison of existing and proposed facilities.

Air quality control planning also requires full detail on the various pollutants emitted by industrial facilities, as the amount of specific pollutants emitted is a basic piece of data needed in investigating and executing control plans.

The completeness of the emissions inventory may be influenced by spatial resolution and temporal resolution permissible, the use to be made of the emissions inventory, and the resources available. For example, the system may inventory one pollutant in great detail, a few pollutants, many pollutants, or attempt an inventory of all pollutants.

3.2.5 Resolution of Source of Emissions

Depending on the purposes of the emissions inventory, considerable variation in the resolution of actual emission sources is possible. If for a certain region just a general emissions picture is needed and the total emission can easily be estimated, an identification of individual sources is not needed.

For the purposes of land use, urban, and regional planning, resolution of emission sources to the level of individual industrial plants, roads, and other specific point, line, or area sources will probably be necessary.

Additional detail to the level of industrial processes and operations which cause the air pollution will be necessary in emissions inventories to be used for licensing or for air quality control planning.

4. Methods

4.1 Data Collection

The compilation of a detailed and useful inventory of air pollutant emissions requires the collection of a substantial amount of accurate and up-to-date technical data.

Source data are necessary to properly identify sources and to calculate emissions, determine compliance status, or support models for predicting air quality. These source data requirements may include source description and details concerning the nature, extent, space and temporal distribution of emissions and exhaust conditions. For inventories related to air quality modeling or short-term air quality standards, the recording of time-dependent emissions may include not only annual averages but emissions for individual seasons, months, days, hours, or even in special cases (e. g. flare emissions) parts of an hour.

When the type and magnitude of the emissions are already known, the emissions inventory procedure can consist of the systematic collection and ordering of information already known or available from questionnaires or interviews. Measured source emissions, based on source test results, should be included whenever practical considering both accuracy and cost. The larger number of sources and the diversity of causes of emissions usually make detailed measurement of emissions on a source-by-source basis impractical. If direct measurements or estimations for certain sources or substances are not practical, emission factors should be applied.

The two approaches used to obtain the data required are: (1) the collection of detailed data on individual emission sources through questionnaires and/or interviews, which is termed the individual approach, and (2) the estimation of emissions based mainly on statistical information, termed the collective approach.

The collective approach is used more often to investigate a large number of similar emitters whereas the individual approach is used for individual emitters.

4.1.1 Calculation of Emissions using Emission Factors

An emission factor is an expression of the rate at which a pollutant is generated as a result of some activity, divided by the level of that activity. The emission factor thus relates the quantity of pollutant emitted to some indicator, such as production capacity, rate of raw material usage, or quantity of fuel burned. For example, the emission of CO from a steel-making process is expressed as the number of kilograms of CO emitted per ton of steel manufactured. Another example is the emission of SO_2 from fuel conbustion, which can be calculated from the sulfur content of the fuel.

Emission factors are not only applicable to the collective approach, but may also be useful for the individual approach to data collection. This is because of the greater uncertainties of one single source test result in comparison to emission factors derived from a few or many similar test results, since one measurement and its test result can only be related to the actual source conditions at the time of the test.

Some countries (e. g., the United States) publish documents containing emission factors, compiled from source tests, material balance studies, and engineering estimates for the major causes of air pollution. Many of these pollution causes are found in other countries and these factors may sometimes apply directly. In other cases, it may be possible, with some critical review, to adapt these factors to local problems. Whenever feasible, however, it is recommended that representative emission factors be developed through tests conducted at the processes which are major causes of pollution within each country.

The accuracy of an emission factor is most directly related to the number of studies performed on the particular sources and/or causes. In general, the most intensive efforts are usually concentrated on the major causes of air pollution and on the most common pollutants. Tests need not be performed at each facility when these facilities use similar processes. One or two representative sources can be surveyed to allow the development of reliable emission factors, which are then applied to the other facilities with similar processes, taking into account any peculiarities.

There are limitations to the applicability of emission factors. In general, emission factors are not precise indicators of emissions from a single source, but are most valid when applied to a large number of sources and causes. When such limitations are taken into account, emission factors can be extremely useful in establishing emission inventories.

There are two general means of calculating emission factors: uncontrolled (as in use in the USA) and controlled or actual (as used by the FRG). A controlled emission factor, in contrast to an uncontrolled emission factor, includes the efficiency of the applied cleaning device. Both approaches are equally valid.

4.1.2 Individual Approach

The first step of an individual approach towards developing an emissions inventory from a certain class of facilities is a literature review which will isolate information re-

garding the characteristics of the likely causes of relevant pollutant emissions. Questionnaires are then prepared for completion by company representatives or by the control agency through interviews and plant visits.

It may be possible, or even preferable, to design a general questionnaire applicable to any type of plant, facility, or apparatus. Although this may preclude obtaining very detailed information, it can be quite suitable for the purposes of the emissions inventory.

In any case, questionnaires to be completed by company representatives should be as brief and clear as possible to minimize the burden on the respondent. Therefore, simple questionnaires for special types of causes may be more desirable than a general type of questionnaire applicable for a broad variety of equipment or facilities.

As a questionnaire is an optimal means of collecting useful data, it should be carefully designed as to format and presentation with the aid of a questionnaire design specialist. A computer data specialist should also be involved in designing questionnaires, to prepare them for computer entry of collected data. Examples of questionnaires can be found in the papers in the Appendix.

Essential queries included in any questionnaire concern the geographic location of the facility and all information related to its identification and definition (e. g. plant name, address, responsible person to contact, and materials processed or used). Other information solicited through the questionnaire may include: the content of all components of the raw materials and end products, the flow of the com-

ponents of interest through each process stage, the actual and potential emission causes in the plant, all stack data, the existing and planned control measures, the mechanical characteristics of control equipment, the physical and chemical properties of the emissions, the method of estimation of emissions and the plant operating and production schedule.

The data collected through the questionnaire approach are first examined for completeness, logic, and accuracy. The data are then processed and classified systematically according to type of emission source and geographic location. Available emission factors obtained from the literature can be used for comparison purposes. By using a computerized system, part of the analysis concerning completeness, logic, and accuracy can be carried out while processing the data (4.2.1).

An individual approach to emissions estimation is strongly recommended for power stations, solid waste and municipal incinerators, and other industrial process plants such as:

- iron and steel-making plants
- primary aluminum, copper and nickel, lead and zinc smelters
- cement works
- stone quarrying and processing plants
- kraft pulping and sulfite pulping plants
- fertilizer manufacturing plants
- petroleum refineries and petrochemical plants
- sulfuric acid manufacturing plants

Criteria to indicate which plants or facilities are to be evaluated by the individual approach can, for example, be based on the number of employees, production levels, or the quantity of contaminants emitted (see the Netherlands paper in the Appendix as an example). An individual approach is not recommended for smaller sources such as dry cleaning plants, and space and office heating systems.

To obtain accurate and useful data, cooperation with industry is essential. Therefore, industrial associations should be contacted and their support obtained prior to collecting information from individual industries.

Once the purpose of the inventory and the manner in which it will be conducted are explained, industry usually is cooperative in finding and reporting the required data. Industry's major concern often lies in the confidentiality of some of the information to be provided. Consequently, the greatest caution must be observed with regard to publication of inventory results so as make it impossible to deduce the confidential emissions data or other data (e. g. production or process information for individual emitters). Some countries, however, do not regard emissions data on a plant-by-plant basis as being of a confidential nature.

Because an emissions inventory is more useful when the information it contains is up-to-date, procedures should be established for the regular submission of data to the responsible organization. These methods may include (1) regular reporting of significant changes in emissions, (2) reporting only upon special occasions such as changes in legislation or in the purpose of the emission inventory, (3) a registration system requiring reporting of installation

or alteration of production or air pollution control equipment, and/or (4) a licensing procedure allowing inventory updating when a license is issued for operation of a new or modified plant or emitter.

4.1.3 Collective Approach

In situations where information needed to estimate emissions on a facility-by-facility basis is lacking, or where it is felt to be unnecessary or not feasible, it is possible to estimate emissions using emission factors, statistical information, and other available data. The collective approach differs from the individual approach in that the former is more suited to the analysis of a number of emitters grouped together than it is to specific emitters. Classes of emitters which cannot be evaluated by means of the individual approach include motor vehicles, railroads, marine vessels, aircraft, residential fuel combustion, forest and field fires and also various types of minor industry (e. g. dry cleaning plants, greenhouses, gasoline filling stations).

Information regarding industrial production and fuel consumption, which is required to estimate emissions from some of these causes, can often be obtained from government departments responsible for collecting these statistical data. This can be supplemented by data published by industrial associations, and by information available from other government departments and agencies. Other requirements are data on population, number of dwellings, number of employees, and land use, etc. These types of information are generally available from census or planning organizations.

Several options exist to estimate emissions from residential heating processes by a collective approach. One option, which may be used to obtain a large scale emission value, is based on total fuel consumption in an area and corresponding emission factors. A more detailed method is based on fuel consumption, population density, and fuel-dependent emission factors. Another detailed procedure involves counting space heating installations and classifying them by type and size. With these data and fuel-dependent emission factors, the emissions of primary pollutants can be calculated for small areas. In nearly all cases, seasonal and even daily variations in temperature and resulting emissions can be taken into account.

Updating procedures may take the form of keeping abreast of revisions or new compilations of any information used in the creation of the emissions inventory, including new census or other government-collected statistics, new land use plans, and new or revised technical information such as emission factors. Changes in the emitters themselves (new industrial facilities or processes, alteration or termination of existing operations, etc.) must also be followed and reflected in updates of the emissions inventory. This last type of information can be obtained from an authority involved in air pollution control permits and registration, or by various reporting requirements.

4.2 Data Processing

The purpose of any data handling system is to provide a mechanism whereby large sets of data can be easily and efficiently stored and then retrieved as desired. The final test is whether the system provides the desired information

to the user in a short time. If a data handling system is designed by using the actual requirement for information to identify the data needed, the requirements of the total system will be understood and the system will meet the expectations of its users.

A basic decision associated with the emissions data processing system is whether or not to use computers. This decision will impact upon every aspect of the system-design time, implementation, cost and maintenance, as well as the operating capabilities of the completed system. Because of its importance to the total inventory system, the decision to create either a manual or computerized system should be made after careful consideration of:

- the volume of data to be stored
- the frequency, size and variety of data or summary retrievals
- the frequency and size of updates, and the availability of resources (information and capital)

Information resources may include storage systems with meteorological data, compilations of emission factors, statistical data concerning automobile density, space heating distributions, etc. A computerized system can be designed to transform these distributions or other statistics, through use of emission factors, into emission and source data.

In situations where it is advantageous to establish an emissions inventory in stepwise or incremental fashion, because of time and/or cost considerations, it is imperative to establish a comprehensive data processing system. Incomplete or overly simplified information can be easily introduced into a comprehensive system; expansion of a severely limited system to one of a comprehensive nature can be very costly as well as time-consuming. One example of an incremental emissions inventory would be an SO_2 emissions inventory from fuel combustion which is later expanded to include SO_2 emissions from other emitters, such as copper smelters.

If computer processing is used, computer specialists and systems analysts for data collection and evaluation should be included in the analysis team. These specialists can assure that the computer system will be responsive to the requirements of the user community.

Regardless of the type of data processing system chosen, a number of factors must be considered in developing a comprehensive system. Due to the diversity of situations for which emission data can be collected and analyzed, these considerations are discussed below in a general context.

4.2.1 Data Auditing

In the context of a total system, computerized or manual, data auditing procedures are responsible for verification of data on input, after they are stored, or in response to inquiries concerning missing or updated data. Data auditing must provide a mechanism for each of these situations, particularly in reference to user inquiries. The purpose of the data auditing procedures is to assure the accuracy and completeness of the emissions data. The following describes various steps of data auditing:

4.2.1.1 Checks of Data during Input

Whenever data are submitted to manual or computerized systems, the input must be checked for format and completeness before it is stored in the system. If the submitted data are in the wrong format, incomplete, in error, or unusable for some other reason, they should be rejected. Rejected data should not be stored in the emissions system as the data would be inaccurate and inappropriate for any further summary or retrieval. This procedure can be used as a formal check with regard to required data reporting.

Once data have passed the formal check and it has therefore been determined that the data are useful and complete, the data are ready to be validated. This procedure incorporates additional checks to determine whether the data submitted reflect a true or realistic situation. These procedures may use high value or reasonable range checks and are essential in determining whether the data are within an expected range and do not indicate some improbable or unrealistic condition. Since this validation check is more subjective than the formal check, data failing the validation check may or may not routinely be stored on the system depending on how useful the data may be for retrieval or analysis. If data failing a validation check are stored, the data should be investigated in some manner to ensure correctness.

4.2.1.2 Checks After Storage

Another auditing procedure consists of reviewing a block of data already stored to ensure that they still reflect the true condition of the emitters. This procedure is used as necessary and is performed by individuals with sufficient background and authority to review the data. This type of check can be seen as a certification.

4.2.1.3 Checks in Response to Inquiries

On occasion, questions as to the correctness of data are raised by data users. For these situations, a procedure should be instituted whereby questions are referred to a knowledgable institution for resolution. Based on the response, appropriate data are updated.

When questions arise regarding the inclusion of additional information not already contained within the system, a verification procedure is initiated. This may result either from questions raised by data users or through independent crosschecking of data records. New data may also be added to the system in the case of new emitters or existing emitters which have inadvertently been left out of the system.

4.2.2 Data Storage

The concepts of computerized emissions data systems vary slightly among the various countries. A subgrouping of information into files assists retrieval of data. The concepts of the Federal Republic of Germany and the United States are described below as examples.

German emissions inventory data files:

- operator identification file - all information on location and nature of plants causing possible environmental pollution
- source identification file - all information on source, nature, size, and location of transition points of air pollutants into the atmosphere

- facility file - all information on nature, capacity, location, and materials processed in the facility
- emissions file - all information on nature, amount, duration, and frequency of emissions including control equipment
- pollutant identification file - information on air pollutants and materials processed or used

The United States emission inventory system:

Data files:

- point source file - all source information on each emitter, including federal facilities
- area source file - all source information on each area (county) emitter
- hazardous pollutants source file - information on each emitter of hazardous or potentially hazardous trace substances
- emission factor file - changes can be made without modifications of other files

Identification files:

- geographical identification file - all federal regional offices, state, Air Quality Control Region (AQCR), and county names and identification numbers
- control equipment identification file - all control equipment names and identification numbers

- process identification file - all process identification numbers as required for the inventory to be used in special modeling programs

The aforementioned files are the main information resources within these emissions inventory systems. Together with auxiliary files and additional information (e.g., air quality data, population data, meteorological data, and industrial fuel usage data), they should form a comprehensive data bank available for the AQMS.

Coding forms for input into the emissions inventories cited above are given in the appended national papers. These forms show in detail which data are be stored.

Similar comprehensive data are contained in the Canadian, Dutch and Belgian systems. These files and forms generally have been derived from the United States and German systems.

4.2.3 Data Retrieval

Data retrieval procedures are the ultimate test of the total emissions inventory system. If accurate, adequate, and timely retrievals can be made from the system to the satisfaction of the users, the emissions inventory system is a successful and well-defined tool. Very few systems are totally successful according to these criteria, but the correlation of the retrievals to the desires of the user community is nonetheless a good measure of the success of a system.

Both raw data and summary information will be candidates for retrieval. Depending on the anticipated ratio of sum-

mary retrievals to raw data retrievals, the system may be designed to maintain summary information already calculated for quick retrieval. This summary information may be in the form of reports or publications available on a shelf in the case of manual or computerized systems. With the computer system, data summaries also may be stored on computerized files which allow for updating each time the raw data are updated.

Simple examples for retrieval are:

- Emission report. This report outputs, for a specific geographical area, emissions of each of the criteria pollutants associated with all the sources represented, as well as the total emissions for all sources.

- Plants emission report. This report presents a listing of the names of plants and the emissions of every pollutant associated with each plant.

Some special retrievals from an emissions inventory data bank may serve for demonstration purposes (Cologne Emission Inventory):

- The evaluation of industrial emissions with regard to the release height showed that:

  1) about 85 percent of the hydrocarbons is released at heights below 20 meters

  2) about 70 percent of all dust is emitted at a height of 60 to 100 meters

- A retrieval concerning different industrial sources showed that only 60 percent of all hydrocarbons is released via defined sources

- Looking at emissions from different facilities or installations, it was found that 50 percent of chlorinated hydrocarbons was emitted from reprocessing plants, about 25 percent was due to chemical processing plants and another 25 percent from surface coating installations or other emitters.

Retrievals from large data sets can be performed via selecting codes (3.1.4). A small number of selecting codes will yield comprehensive detailed output data. A large number of selecting codes (strongest restrictions) will yield only few data with very specific information content.

One consideration unique to emissions data is the disposition of confidential data. Some policy will be necessary to recognize data as confidential or not. If data are confidential, the retrieval procedures must recognize this status and prevent these data from being available to unauthorized personnel.

4.2.4 Data Summaries

A summary of data is generally used either to check data for completeness or to obtain information on emission totals. Data summary procedures should be developed early in the design of any emissions inventory system. Decisions concerning the type of data summaries or analyses required will, in turn, indicate the raw data to be collected. Each item of data collected should have a definite purpose, as an identifier or data value, or in the calculation of summaries.

Since summaries are at least one level removed from the raw data, procedures previously described under data auditing (4.2.1) must assure that the data are complete and accurate and, also, that all the statistical assumptions required of the summary analyses can be verified. The typical user of the data system may never see the basic data, but rather will rely on the integrity of the data handlers to provide him with accurate information. The importance of this trust is emphasized. If the data summaries do not use valid statistical techniques or do not take into consideration any relevant properties of the data, then the user may reach incorrect and possibly costly conclusions.

Data summaries represent very simple types of data retrievals. The following is an example of a data summary and possible conclusions to be drawn from such a summary:

> After detailed data collection and storage of data for an industrial plant, evaluation of the data first is done, usually based on a summary of the quantities of the air pollutants separately being emitted from the total plant or from the different facilities. This summary then may show relevant critical emissions concerning pollutants or their quantity. Action then should be taken to reduce the quantity of a special pollutant, if present only at a single or only very few facilities. If the summary does not allow such a conclusion directly, further evaluations (data retrievals) must be made.

4.3 Data Flow Systems

The handling of emissions inventory data involves various levels of administration and possibly private organizations.

The responsibility for gathering and maintaining the emissions inventory rests with the government agency. In some cases, this responsibility may be delegated to local agencies. The systems in use by the NATO countries vary only slightly.

4.3.1 Flow of Information into the System

Regardless of which agency has the responsibility, the first step after establishing an emissions inventory system is to gather inventory data. The original data are obtained from questionnaires (e.g., existing industrial plants) or a permit system (e.g., new plants) and are updated through the same mechanism or by inspections. The next step is to estimate, calculate, or verify emissions data.

Once data are entered into the system they are submitted to other interested government agencies (e.g., the local authorities in the Netherlands).

In general, the input into the emissions inventory data bank involves several different agencies such as the firms responsible for emissions (polluters), licensing authorities, independent expert agencies, lower administrative bodies, and government agencies.

Further information on data flow, control and updating is outlined in national papers in the Appendix.

4.3.2 Flow of Results from the System

Once the data are in the emissions inventory system, they are accessible to the personnel responsible for the data. Government agencies or local agencies, such as licensing

bodies, can request data or summaries. The aspect of confidentiality is mentioned in most national papers. The use of confidential data in most emissions inventory systems is limited to aggregated statistics only; individual information is available outside the emissions inventory only with approval of the submitter.

Status reports and management reports as well as certain publications may be generated periodically. However, the publications may contain summary information only because of confidentiality reasons.

5. Check List for Establishing an Emissions Inventory System

In the foregoing sections and in the technical papers (see the Appendix), a great deal of the experience obtained by the participating countries in developing and operating emissions inventory systems has been presented. A number of suggestions have evolved from this background, as outlined below.

5.1 Planning an Emissions Inventory

When planning an emissions inventory, three major issues should be addressed: (1) the objectives of the inventory, (2) the geographical area that the inventory will cover and, (3) the emitter categories to be included.

There are several objectives of an emissions inventory system. They may include (1) the planning and directing of improvements in a high pollution area and (2) the

planning of new industrial facilities, highways, residential areas, etc. In all cases, the level of detail (resolution) required for the desired objectives should be considered along with the instruments available to carry them through.

The geographical area to be considered may be an entire continent, a country or its major areas, or only certain urbanized areas. In defining the source categories that will be taken into account, the planner should carefully consider which categories are to be included. After designation of the source categories, a decision should be made whether to cover sources of all sizes or only the major ones. For each case a different level of detail will be required, thus influencing the character of the inventory.

5.2 Designing an Emissions Inventory System

After consideration of the objectives of the system, the availability of data, and the funds available for data collection and handling, three issues should be addressed in designing an emissions inventory system: (1) elements covered by the inventory, (2) the required level of detail (resolution) of the elements and, (3) the required relationship of the emissions inventory system with other data systems.

Certain elements are common in the systems of all participating countries. These are:

- emitter identification
- activity and equipment
- source data
- control equipment and efficiency
- emissions data (amount, pollutant, location and time).

5.3 Collection of Data

For successful collection of data, the following suggestions are recommended:

1) Establish good cooperation with sources of information (e.g., industry, local authories).

2) Ensure confidentiality of data.

3) Minimize the burden on the respondents.

4) Perform representative source testing whenever feasible.

5) Provide ease of computerization.

Suggestions (1) through (3) are meant to provide optimal access to available data, thus ensuring optimal quality of the collected data. The burden on the respondents can be greatly reduced if they are not required to fill out the data forms. A more efficient procedure which results in data of better quality is one in which the respondents just collect available data, while the forms are filled out by specially trained emissions inventory personnel.

5.4 Data Handling

The following suggestions are offered on data handling:

1) Determine the need of computerization according to the volume of data to be collected and the required frequency and type of data retrieval.

2) Identify specific summaries and retrievals associated with the objectives of the emissions inventory system.

3) Allow for adequate growth of the data files.

Suggestions (1) and (2) are meant to ensure that the results will address the original objectives of the inventory system. Data which do not satisfy the stated requirements can cause problems for any data system.

5.5 Updating the Emissions Inventory

In most cases, the regular updating of the data system is desirable. To ensure that the system is updated, a reporting system should be established. This could be done by regular reporting (e.g., on a yearly basis) or reporting only when modifications greater than a certain extent occur.

Updating also could be combined with the procedure of granting new operating permits for installations on which major modifications have been made. Whether size modifications should be reported depends on their effect on the sum of the emissions of the pollutant in the area.

5.6 Revising the Emissions Inventory System

A regular evaluation of a data system is needed to ensure that the system still meets the original objectives and/or new objectives. If the system is no longer in accordance with the objectives, the necessary modifications should be made. This may result in the elimination of the system elements that are no longer needed.

6. Summary of Technical Papers on Emissions Inventories

6.1 Belgium

This paper gives a description of a study of the methodology for establishing an emissions inventory system. Three restricted test areas were chosen in the country, in which the methodology is applied.

Because a high resolution concerning time, space, pollutants and emitters was intended, these test areas were very small ($\pm$ 100 km^2).

Data collection was started in 1976 and the data pertaining to 1979 should be completely in the data-bank by the end of 1980. The system will then be kept up-to-date and possibly be expanded to the whole country.

The paper first gives an outline of the objectives of an emissions inventory system. Further a detailed description is given of the procedure used for the data collection. Different institutes are charged with the collection of the data pertaining to the emissions caused by transportation, by space heating or other minor sources and by industrial facilities. While for the former two emitter categories the collective approach is applied, an individual approach is used for the emission data from industrial origin. The latter approach is described in some detail and the questionnaires used are given in addendum I. The methodology for this data collection was developed from the system used in the Netherlands and in Germany. It is heavily modified and adapted to the local situation. The methodology used for the determination of traffic density, as part of the emission data collection related to transportation, is different from that used in other countries.

6.2 Canada

A first document describes the purposes for, and the objectives envisaged in, establishing in 1972 a National Emissions Inventory System. The methodology utilized is detailed for the two types of inventories performed, one for hazardous air contaminants, the other for the more common air contaminants. It indicates that emissions information can be developed through estimates based on emission factors and other available data, and/or through questionnaires and interviews. An example questionnaire is provided. It identifies and defines the types of emission sources investigated which fall in one of the following categories: industrial processes, fuel combustion in stationary sources, transportation, solid waste incineration, miscellaneous sources. Presently the inventories cover 65 different types of emissions sources ranging from important emitters such as gasoline-powered motor vehicles, forest fires, and primary copper and nickel production, to lesser contributors to the total pollution load such as magnesium production, concrete batching, and glass manufacturing. It further indicates that inventories have been completed for 17 different contaminants, and that inventories for another 12 contaminants are being developed.

The other document describes the data handling techniques used in developing and maintaining the National Emissions Inventory System. It discusses the reasons for initiating in 1974 a gradual transformation from a manually established to a computerized system, and gives an overview of

the batch type computer system adopted and of the important modifications made to it over a two year period. It provides example forms used to input data to the system. Finally an indication of the manpower and financial resources required to establish and operate the system is given.

6.3 Federal Republic of Germany

In 1969 the establishment of regional high resolution emissions inventories was initiated. The realization of an inventory system specially developed to meet the air quality management needs in highly industrialized areas began in the Cologne region. Meanwhile, the Federal Immission Protection Act of 1974 claims that emissions inventories - and clean air plans - be drawn up for areas with a heavy pollution load. For a number of regions emissions inventories are already available.

The paper describes the emissions inventory system of Northrhine-Westfalia which has been taken over by some of the other Laender. In this data bank the various aspects of emissions and their origins are collected in separate data files:

- substance released
- operator of emitting facility
- structure and purpose of facility
- source (transition location) and
- temporal behavior of emission rate.

The whole system is designed to be extremely flexible so that the degree of resolution can be chosen depending on the circumstances.

The data forms used at present for the individual investigation of industrial emitters and for the collective investigation of the remaining emitter categories are presented. Some examples are in-

tended to illustrate the inventorying procedure. These data forms have to be completed by experts on the basis of inquiries or questionnaires.

The principle of flexibility is also valid for the evaluation of the emissions inventory. A survey of the present possibilities is given.

6.5 Netherlands

The first paper describes the objectives, the methods and the technical and administrative procedures of the Dutch national emission inventory. This inventory also covers waste water and chemical waste materials. A first round was started in 1974 and is being carried out province by province. In 1981 a new round is expected in order to update the information.

For industrial plants with more than 10 workers the data collection is done on an individual basis. All other emitters, such as small industrial firms, households, traffic, trade and agricultural activities are mainly treated on a collective basis. Also emissions from natural sources are registered in this way.

The system for handling and processing of the data from individual industrial plants was derived from the German emission inventory developed for the state of Nordrhein-Westfalen, but adapted according to local requirements. For the handling and processing of the data from collectively treated emitters, a completely new system was developed.

The second paper is a translation into English of most of the manual used by the data collectors approaching individual industrial plants. Also the questionnaires/coding forms and most of the code lists are included.

6.6 Norway

This paper contains a short summary concerning emission inventories in Norway.

The first comprehensive emission inventory was undertaken by The Federation of Norwegian Industries. A questionnaire was sent out to some 1500 industrial establishments. Data were collected on all gaseous, liquid, and solid wastes which could reach the recipient, i.e. the air, water and soil. Supplementary data on fuel oil consumption in Norway were collected by the oil companies.

In addition to these efforts, emission data have also been gathered by semi-governmental and governmental institutes.

All of these basic data have been used to compile a number of emission inventories on specific air pollutants. SO_2 and particulates have received the most attention, but inventories of nitrogen and hydrocarbons have also been made.

In one of these emission inventories, Norway was divided into 140 grid squares and the SO_2-emission were divided into:

a) continuous emissions and
b) variable emissions

A number of emission inventories have also been made for specific types of industries in Norway. These give the total amounts of the most important air pollutants emitted from the industrial processes and operations in question.

For two areas in Norway, the Oslo and Grenland areas, special emission inventories have been made with a grid size of 1 km^2.

6.7 United States

This paper consists of a general introduction and chapters on emissions inventory techniques, data flow, and automation of the U.S. emissions inventory.

The scope and structure of the emissions inventory system is outlined in detail. The methodology of handling point and area sources is described. Large plants (emissions over 100 tons per year of any criteria pollutant) are defined as point sources, while smaller sources of common pollutants are grouped as area sources. A collective approach is applied to many of the emittting sources, using emission factors. Different groups of sources are considered separately: motor vehicle traffic, industrial area sources, space heating, and field and forest fires.

A comprehensive description of data flow and handling is given. The responsibility for gathering and maintaining the emissions inventory rests with several levels of government; e.g., local, county, state, and federal. The participation of each governmental body is explained.

The U.S. National Emission Data System (NEDS) is a computerized data handling system for the five criteria pollutants (particulates, SO_x, NO_x, CO, and hydrocarbons). The subsystems which process the point and area source data are described. The NEDS data files are explained, updating procedures are described, and various retrieval capabilities of the system are identified.

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ANNEX I

Names and Addresses of Panel Members (as of Fall 1978)

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ANNEX II

NATO/CCMS Documents on the First Air Pollution Pilot Study (available at: NATO/Committee on the Challenges of Modern Society, NATO Headquarters, Brussels, Belgium)

AIR POLLUTION (No. 5)

Proceedings of the 2nd Meeting of the Expert Panel on Air Pollution Modeling, (26 - 27 July 1971, Paris, France). Out of stock

AIR POLLUTION (No. 6)

Guidelines to Assessment of Air Quality (Revised)

APPENDIX A	Assessment of Air Quality in Ankara (February 1973)
APPENDIX B	Assessment of Air Quality in St. Louis (February 1973)
APPENDIX C	Assessment of Air Quality in Frankfurt (June 1974)
APPENDIX D	Assessment of Air Quality in Oslo (February 1973)
APPENDIX E	Assessment of Air Quality in the South Holland Region (December 1973)

AIR POLLUTION (No. 7)

Quality Criteria for Sulphur Oxides (November 1971). Out of stock

AIR POLLUTION (No. 8)

Air Quality Criteria for Particulate Matter (November 1971). Out of stock

AIR POLLUTION (No. 10)

Air Quality Criteria for Carbon Monoxide (June 1972)

AIR POLLUTION (No. 12)

Control Techniques for Sulphur Oxide Air Pollutants (October 1973)

AIR POLLUTION (No. 13)

Control Techniques for Particulate Air Pollutants (October 1973)

AIR POLLUTION (No. 14)

Proceedings of the 3rd Meeting of the Expert Panel on Air Pollution Modeling
(2 - 3 October, 1972, Paris)

AIR POLLUTION (No. 15)

Air Quality Criteria for Nitrogen Oxides (June 1973)

AIR POLLUTION (No. 18)

Control Techniques for Carbon Monoxide Emissions from Stationary Sources (October 1973)

AIR POLLUTION (No. 19)

Control Techniques for Hydrocarbon and Organic Solvent Emissions from Stationary Sources (October 1973)

AIR POLLUTION (No. 20)

Control Techniques for Nitrogen Oxide Emissions from Stationary Sources (October 1973)

AIR POLLUTION (No. 29)

Air Quality Criteria for Photochemical Oxidants and Related Hydrocarbons (February 1974)

AIR POLLUTION (No. 30)

Proceedings of the 4th Meeting of the Expert Panel on Air Pollution Modeling, (28 - 30 May 1973, Oberursel, Germany)

AIR POLLUTION (No. 33)

Final Report (May 1974)

AIR POLLUTION (No. 35)

Proceedings of the 5th Meeting of the Expert Panel on Air Pollution Modeling (4 - 6 June 1974, Roskilde, Denmark)

AIR POLLUTION (No. 41)

First Follow-up Report (December 1975)

AIR POLLUTION (No. 50)

Second Follow-up Report (December 1976)

AIR POLLUTION (No. 67)

Third Follow-up Report (November 1977)

AIR POLLUTION (No. 96)

Fourth Follow-up Report (October 1978)

AIR POLLUTION (No. 6, Appendix C revised)

Assessment of Air Quality in Frankfurt (December 1977)

ANNEX III

NATO/CCMS Documents on the Pilot Study on Air Pollution Assessment Methodology and Modeling
(available at: NATO/Committee on the Challenges of Modern Society, NATO Headquarters, Brussels, Belgium)

Air Pollution (No. 42)

Proceedings of the 6th International Technical Meeting on Air Pollution Modeling and its Application
(24 - 26 September 1976, Frankfurt/Main, Germany)

Air Pollution (No. 51)

Proceedings of the 7th International Technical Meeting on Air Pollution Modeling and its Application
(7 - 10 September 1976, Airlie House, USA)

Air Pollution (No. 70)

Bibliography on Grey Literature on Air Quality Modeling, Part I (Applied Models) (October 1977)

Air Pollution (No. 71)

Air Quality Management Systems (AQMS) (October 1977)

Air Pollution (No. 88)

Bibliography on Grey Literature on Air Quality Modeling, Part II (New Modeling Techniques) (October 1978)

Air Pollution (No. 89)

Glossary of Terms Generally Used in Air Pollution Assessment Methodology and Modeling (October 1978)

Air Pollution (No. 80)

Proceedings of the 8th International Technical Meeting on Air Pollution Modeling and its Application
(20 - 23 September 1977, Louvain-la-Neuve, Belgium)

Air Pollution (No. 99)

Introduction to Air Quality Modeling (October 1978)

Air Pollution (No. 100)

Air Pollution Emissions Projecting (October 1978)

Air Pollution (No. 101)

Uses and Needs for Air Quality Modeling (May 1979)

Air Pollution (No. 102)

Fundamentals for the Application of a Gaussian Plume Model (April 1979)

Air Pollution (No. 104)

Air Pollution Emissions Inventory Systems
(October 1978/July 1979)

APPENDIX A: Emissions Inventory in Belgium
APPENDIX B: Emissions Inventory in Canada
APPENDIX C: Emissions Inventory in Germany, Federal Republic of
APPENDIX D: Emissions Inventory in The Netherlands
APPENDIX E: Emissions Inventory in Norway
APPENDIX F: Emissions Inventory in the United States of America

Air Pollution (No. 106)

Practical Demonstration of Multiple Source Urban Air Quality Modeling (Gaussian Plume) (August 1979)

Air Pollution (No. 71, Revised)

Air Quality Management Systems (AQMS) (April 1979)

Air Pollution (No. 105)

FINAL REPORT (October 1979)

Air Pollution (No. 103)

Proceedings of the 9th International Technical Meeting on Air Pollution Modeling and its Application
(28 - 31 August, 1978, Toronto, Canada)

Air Pollution (No. 108)

Proceedings of the 10th International Technical Meeting on Air Pollution Modeling and its Application
(23 - 26 October, 1979, Roma, Italy)